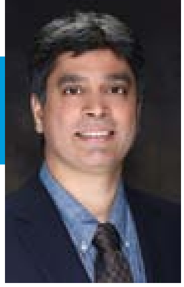

AN INSIDER'S PERSPECTIVE

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Cut Wire or Cast Steel Shot – A Review

INTRODUCTION

One of the challenges in our industry has been to increase the awareness for shot peening, but with concerted efforts we are seeing this move in a positive direction. During a re-cap after the recent EI USA Shot Peening Workshop, the instructors all agreed that the understanding and participation level of students had increased over the years. The questions and comments discussed in the classes were quite advanced. That said, I would like to highlight a recurring conversation at the workshop that will benefit from additional elaboration. This discussion pertains to the choice between conditioned cut wire (CW) shot and cast steel shot.

CUT WIRE OR CAST STEEL SHOT – WHICH ONE IS BETTER?

I was part of interesting discussions during a class on cut wire media from Toyo Seiko at the recent workshop. Conversations during this class prompted me to conduct additional research, courtesy of Toyo Seiko and Ervin Industries. These companies are two leading manufacturers of cut wire shot and cast steel shot respectively.

Common practice is for end-users to specify peening media type, size and sometimes the hardness. For example, the drawing might require you to peen the landing gear component to an intensity range of 0.012 to 0.015A using S230 for 100% coverage. The specification might even narrow down the scope to the use of ASR (regular hardness: 45 to 52 HRC) or ASH (high hardness: 55 to 62 HRC) media. Such specifications are now being enhanced to include an optional media type. The same specification will now read, 0.012 to 0.015A using S230 or CCW 28, with the scope sometimes further narrowed to stipulate the use of AWCR (regular hardness: 45 to 52 HRC) or AWCH (high hardness 55 to 62 HRC). Being a relatively new type of media as compared to cast shot, cut wire shot (conditioned) is a cold-drawn product, cut into cylindrical pieces and conditioned (rounded) by bombarding it against a fixed target. This process rounds the sharp edges; thereby attempting to eliminate part damage due to edge sharpness. The length of the cylindrical portion is the same as the diameter of the cylinder. This results in an almost spherical shape after conditioning. Drawings calling out for the use of CW shot also specify the desired level of conditioning, such as single conditioned, double or special conditioned cut wire. VDFI8001 (Deutsche) standards categorize this as G1, G2 and G3. Evaluating such levels of conditioning are visual and the AMS standards committee continues to explore means of quantifying them.

As compared to CW shot, cast steel shot is a tempered martensitic material manufactured by water atomization of molten steel and air or water quenched. Post-atomization, the product is screened multiple times and heat treated to achieve the desired hardness range.

Some common beliefs in our industry include:

- Cast steel shot fractures rapidly and is unsuitable for shot peening
- CW shot lasts longer than cast steel shot
- CW shot is not liable to damage part substrate since it does not fracture like cast shot
- Transfer of impact energy (and resulting residual stress levels) is better with CW shot than cast steel shot
- CW shot is more expensive than cast steel shot

WHAT DETERMINES DURABILITY?

Let us first try and understand the different specifications pertaining to this media. The primary attribute of any shot peening media is its ability to transfer impact energy effectively and repeatedly. This attribute is largely determined by the media's chemical constituents. Please refer to "The Critical Role of Metallic Shot in Achieving Consistent Shot Peening Results," (*The Shot Peener*, Fall 2017) for an in-depth report on this topic. Listed in Table One are the percentage chemistry of the two media as in AMS and SAE J documents.

Table One

	AMS 2431/1 & /2	SAE J827	SAE J441	AMS 2431/3 & /8
Percentage	ASR & ASH Cast Shot	High-Carbon Cast Steel Shot	Cut Wire Shot	AWCR & AWCH Cut Wire Shot
Carbon	0.80 to 1.20	0.80 to 1.20	0.45 to 0.85	0.45 to 0.85
Manganese	1.20 max*	0.60 to 1.20	0.30 to 1.30	0.30 to 1.30
Silicon	0.40 to 1.50	0.40 min	0.15 to 0.35	0.15 to 0.35
Phosphorus	0.050 max	0.05 max	0.040 max	0.040 max
Sulphur	0.050 max	0.05 max	0.050 max	0.050 max

* min MN content based on shot size

As seen in Table One, the chemistry of both media types is comparable in most of the constituents, with some minor exceptions. The carbon content requirement is lower with CW shot than cast. In general, lower carbon content will lead to the shot absorbing most of the impact energy, leaving less for the actual peening. However, one could also make an argument that higher carbon content could render the media brittle and susceptible to fracture. Overall, the carbon content in both media types draws a balance between the positives and negatives. Silicon (Si), in higher percentages, adds to the durability and acts as a de-oxidizing agent. The higher Si percentage in cast shot as compared to CW shot should address any concerns of loss of durability due to its higher carbon content.

In summary, if we were to look at chemistry determining durability, we will be reviewing comparable products without much of a chemical compromise.

In the case of CW shot, all commercially sold material either conforms to SAE, AMS and VDFI standards. SAE or industrial grade material, in the case of cast steel shot, is commonly used in cleaning applications. However, when not specifically stated in the requirement, it is not uncommon for the shot peener to use SAE grade material for shot peening as well. A quick look at Table One will point to comparable chemistry between SAE and AMS grade cast shot. The differences in the two grades are more to do with size (screening tolerance), shape tolerance and hardness ranges. Table Two lists those specific differences.

Table Two: Specification Comparison – SAE & AMS for Cast Steel Shot

Characteristic / Defect	SAE J827 (J444 for screening)	AMS 2431-1
Particle shape	≤ 5%	Specs list marginal and unacceptable shapes – tighter tolerance than SAE J827
Voids	≤ 10%	≤ 15%
Shrinkage	≤ 10%	≤ 15%
Cracks	≤ 15%	≤ 15%
Microstructure	≤ 15%	
Screening		Tighter than SAE J444

Needless to say, AMS grade cast shot goes through several additional rounds of processing in order to maintain conformance, leading to a higher price as compared to SAE grade material.

SHOT HARDNESS, DURABILITY AND FRACTURE

Dr. Yoshihiro Watanabe, President of Toyo Seiko Co. Ltd. in Japan, presented a paper at the Fourth International Conference on Shot Peening, October 1990 in Tokyo, Japan. His work explains the effect of broken media particles on shot peening. He categorizes "hard shot peening" as peening to arc heights greater than 0.7 mmA (0.0275"A) in order to increase the fatigue life of case-hardened components, typically auto transmission gears that are designed to transmit power from high-performance engines. Citing an increase of 25% to 30% in fatigue strength with hard peening as compared to conventional peening, Dr. Watanabe's study takes into consideration two shot samples, at different hardness, HV 550 and HV 700 (55 and 66 HRC). His findings—even though they don't specify the exact specifications of Shot A and B—draw the following conclusions in addition to increase in fatigue strength cited above:

i. High-energy bombardment required to develop increased intensity (0.7 mmA) and corresponding fatigue life also resulted in greater number of broken particles. This was more evident with the media sample of greater hardness.
ii. Harder shot increased the surface hardness of the specimen.
iii. Residual stress generated was comparable between the media types for the lower hardness media, and significantly different for the higher hardness media.
iv. With the lower hardness shot, neither shot sample yielded detrimental quantity of broken material, but that wasn't true in the higher hardness shot. High hardness Shot B disintegrated into increased quantity of smaller particles, leading to scattered peening results that contributed to less than desirable peening quality.

Though the identity of Shot A and B are not known in this study, one can conclude from Dr. Watanabe's findings that higher-hardness media particles, though beneficial for specific high-intensity applications, could lead to greater particle breakdown and not achieve the desired fatigue resistance. Most shot peening machines operate with an inline size classifier sized to remove broken (by size) peening media, and sometimes a spiral separator to separate particles with sharp edges. Also, nothing can replace regular media inspection offline to the main process. So, does cut wire media actually last longer than cast steel shot?

I continued this discussion with Michael Konecny, Quality Manager at Ervin Industries. Ervin is a quality supplier of SAE and AMS grade shot peening media. Mr. Konecny explained the logic and corrections behind the myths in our industry surrounding cast steel shot. "Almost all cleaning applications out there use SAE grade material, with little importance placed on certification, until they see comparative results when we test media in our lab. Specifications have been formulated for a reason and their compliance will result in media that has predictable durability, particularly to address issues found by Dr. Watanabe in his research. Of course, broken particles are never good, especially in critical peening projects." Mr. Konecny added, "All AMS material manufactured at Ervin goes through multiple levels of conditioning and spiral separating (to remove non-rounds) before we certify it to be compliant."

As a cast steel shot supplier, Ervin regularly conducts comparative studies of cast steel shot with cut wire shot with the following results. A summary of two recent tests follows.

Peening Media	Durability %	Transmitted Energy
S330M (47 to 56 HRC)	78% of CCW35	103.1% of CCW35
S390M (47 to 56 HRC)	85% of CCW47	91.2% of CCW47

Given the nature of the process, it is not possible to generalize and advocate for the use of one media type over the other in terms of durability and cost-benefit. Every other aspect being equal, the end-user has to make the determination for the optimum choice.

In terms of transmitted energy, the calculation was done in an Ervin Test Machine that generates a velocity of 200 feet per second. In a production machine, this velocity can be increased by increasing the wheel speed or the air pressure (in an airblast machine) to increase the transmitted energy up to the threshold value for a particular size of media.

Cast shot will fracture as compared to CW shot that wears to a smaller size. Ultimately, both media types that are no longer within tolerance/specifications have to be eliminated from the peening system using process control components.

CONDITIONING, RESIDUAL STRESS AND SHOT FRACTURE

There is no doubt that a cold-drawn product, absent of the voids and other imperfections seen in castings, will wear differently due to its manufacturing process. Toyo Seiko provided me with their comparison documentation that placed CW shot at significantly higher durability than claimed by Ervin's cast shot. Their research interestingly also revealed that the fatigue strength developed by both media types was comparable, except at high hardness, as seen in their study cited earlier. I came across more research presented by Advanced Remanufacturing Technology Center in Singapore comparing AWCR 14 and ASR 110. It validates that residual stress values were indeed comparable even with the smaller size of media, giving us a comparison over a sizeable range. Cut wire, in its "as cut" form has sharp edges and it is critical that conditioning be carried out effectively. That said, other than random visual inspection, there is no quantitative process to determine the extent of conditioning and the percentage of media that has been conditioned. Moreover, there is insufficient evidence that proves CW shot does not fracture. It is imperative that CW shot be 100% conditioned to avoid the risk of as-cut particles with sharp edges residing in the new CW shot. This is of greater relevance when working with smaller-sized media where the diameter has to match the length of the cylinder for proper size control.

Random sample of conditioned CW shot could include traces of insufficiently conditioned, cylindrical particles.

Cast shot fails by fracture. However, this fatigue occurs later in the life of the shot particle and after measurable diameter wear. With this, fractured shot could remain in your machine until it wears down to a size that the classifier screen identifies as being too small. Whether this fractured shot in the interim, with its partial sharp edge (instead of an intended smooth dent), could damage your component is difficult to predict given the relatively random nature of the discharge process from the blast wheel or nozzle. Moreover, the impact value from a broken particle is likely too minimal to cause surface damage.

In other words, both media types have their strengths and weaknesses. With vacuum-carburized furnaces replacing their gas-carburized counterparts due to lower CO_2 emissions from the former, parts being produced have hardness exceeding 62 HRC. There might be a niche market that requires hard peening media that guarantees hardness greater than this value. Special-hardened CW shot might be the answer in that market over H hardness shot that provides a minimum hardness of 60 HRC without an upper limit.

SUMMARY

Shot peening applications have different variables and one solution will not address everything. Variables are not only in media options, but in equipment type and process, too. Two different media chemistry values, both conforming to specifications, could lead to slightly different results which is why specifications will give you a target range over a finite value. Consider the data in our discussions and determine which solution will work best for you. After all, that is the reason the specification has not dismissed one media type as ineffective and given you the choice to select.